In the Absence of Standards, Low Impact Development Might Equate to High Impact Development

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Introduction

The low impact development (LID) concept is a good beginning for much-needed change in the way we develop land. LID, as a concept, describes a collection of goals and practices that have a higher probability of protecting streams if watersheds were developed employing the practices described.

However, the LID concept is not useful until is refined into a set of standards that are then adopted into municipal code. The translation of concept into municipal code presents much opportunity for subjectivity. For example, is "cluster development" compatible with LID? How many structures (i.e. impervious area) per acre can be constructed before exceeding thresholds of unacceptable impacts on streams? Is a short, wide driveway equivalent to a long, narrow one with the same impervious area? Does a "rambler" style home with a rain harvest system have fewer impacts than a home with a small footprint with no rain harvest system? Is a "green roof" better than one with a rain-harvest system? Should strict fire ratings for structures be part of LID code? Should the forest reserve be separated from development in "tree tracts"?

We have nearly a century of experience in writing standards for traditional urban landscapes. Many of the standards in code today have been refined through trial and error (many trials and many errors). Erosion control protection standards, for example, are still a work in progress. But we have no similar experience with LID standards. Faced with possibly the last chance in the Puget Sound Basin at preserving watersheds in the path of development, how should standards be crafted?

Guiding Principals

LID ("65/0") code is intended to protect watersheds and aquatic life in the path of development. In the introduction to the Salmon in the City abstracts (1998), characteristics of a healthy watershed and constraints on development if such characteristics are to be maintained are described. They are:

1. 60% of the Watershed Must Remain (or be restored to) the Forested Condition. Modeling studies since the Salmon in the City conference have nudged the forest protection area up to 65% of the watershed. Actual required forest preservation depends on soils types and slopes in the watershed.

   It is also believed that the <u>pattern</u> of clearing contributes to harmful changes in hydrology. Thus large clear-cut patches would be more harmful than removal of small clumps of trees, say at the ¼-acre level. Hicks (1991) has shown that clear cut patches of 25% of a watershed can have measurable and lasting impacts on watersheds. Though it is believed to be so, no data can be found to support the contention that "thinning" a watershed forest by 25% would be less harmful than a patch cut of the same area.

   If the patch-cut technique of logging has unacceptable impact on streams, it follows that clustering development in a patch cut will add to impacts. It further follows that the impervious area must be isolated within native vegetation buffers. Development reduces evapotranspiration, and impervious area seals soils making them unavailable to store and infiltrate precipitation. If no overland flow discharge to surface water is permitted, remaining undamaged soils and vegetation must take on the burden of additional infiltration of runoff from impervious surfaces. Extra infiltration capacity in these remaining undamaged soils is limited and in some areas (e.g. near the bottom of slopes) may be non-existent. Because some soils at some locations have no extra capacity to infiltrate, it is imperative to avoid concentrating and conveying runoff "to the forest". It is better design to "bring the forest" to where it is needed.

2. No Drainage Collection System. Horner and May (1998) and others have shown that "effective" impervious area can be harmful even though such areas may be a small percentage of a watershed. Thus municipal code must require that stormwater is not to be collected, but rather is to be infiltrated/evapotranspired as near as possible to where it fell as rain. To achieve this goal on poor soils, minimization of forest disturbance and impervious area is implied.

3. Protect Riparian Zone with Wide Buffers

Together with the code needed to implement them, the author refers to these guiding principles as the "65/0 standard for development". "65/0" means that 65% forest cover remains (or is restored) after development and that 0% overland flow runoff is to be discharged from the site.

Only Code for New Development (on poor soils) Discussed
Code discussed herein is intended to regulate new development. Code for re-development (intended to restore already damaged watersheds) would have the same guiding principles, but implementation might be quite different. The omission of this subject does not imply that low impact redevelopment of existing urban watersheds is not important or should not be attempted. To the contrary, jurisdictions may rightly decide to protect undeveloped watersheds while using the engine of redevelopment to restore urban watersheds.

It is also assumed for purposes of this paper, that code will regulate new development on poor soils. Poor soils are often saturated much of the winter even in the forested condition and are incapable of supporting standard infiltration facilities. Code suggested herein targets development on these soils. On very well drained soils, such as outwash, infiltration of runoff from even large impervious areas is feasible usually without special code. Benefits of LID (65/0) practices on outwash soils do exist, but they are not discussed in this paper.

Performance Code vs. Prescriptive Code
"Performance code" does not specify how a project must be built but only the results expected when construction is completed. Such code provides project proponents with maximum flexibility. But it also puts a burden on proponents in that they must create original designs that might or might not be accepted by the approving jurisdiction. Uncertainty is a deterrent to developers. Such code may also be difficult to administer by the jurisdiction in that staff may not have the expertise to judge if the proposed design is likely to succeed or fail.

"Prescriptive Code" describes in specific detail how each component of a project is to be constructed. This type of code leaves the proponent less flexibility, but increases certainty that if the rules are followed the project will be approved. Writing brand new prescriptive code carries the dangers of unintentionally leaving loopholes to skirt guiding principals or making code unnecessarily onerous to no purpose. In the first instance watersheds will not be protected and in the second protests will be raised that might tempt some jurisdictions to abandon LID standards.

Most municipal code is prescriptive. This paper discusses prescriptive code to implement LID designed to the "65/0" standard.

Global Changes in Policy Not Discussed
Major shifts in policy to effect LID standards (e.g. abandoning automobile-based systems in favor of public transit) are not discussed in this paper. Although such shifts offer great strides toward low impact development and watershed protection, they require cultural changes discussion of which is beyond the scope of this paper.

Short List of Code to be Revised

Low impact development concept implies substantial changes to municipal code. At minimum the following code / policy would be modified:

- Clearing
- Grading
- Critical Areas

- Zoning
  - Structures per acre / Forest per acre / Impervious per acre
  - Block Length
  - Structure Height
  - Multi-Family
  - Cottage Code
  - Condominium Code
  - Cluster Development
  - Planned Unit Development

- Parking
  - Under structure
  - Alternate Materials
  - Stormscaping
  - Materials
  - Compaction of subgrade
  - Clearing and grading for parking

- Roads / Streets
  - Clearing and grading for roadway
  - Arterials
  - Planter strip / bioretention
  - Clear Zones
  - Sidewalk vs walkways
  - Materials (Pervious concrete / pavers / vegetated pavers)
  - One-way road standard
  - Boulevard standard
  - Lane width
  - Prism (no curbs / on fill / bioretention / crowns / super elevation)
  - "No excavation" roadway design
  - Road construction parallel vs. perpendicular to slope
  - Use of ballast for storage and treatment
  - Compaction of subgrade (load spreading)
  - Maintenance of in situ treatment

- Stormwater
  - Runoff Distance Maximum
  - Roof runoff /
  - Rain harvesting
  - No collection system / outfalls
  - Evapotranspiration control
  - Infiltration control
  - Bioretention design (esp. on slopes)
  - Role of biologically active zone (when infiltrating)

- Uniform Building Code
  - Gutters
  - Stem Walls
  - Basements
  - Foundations
  - (Concrete) Slab on Grade
  - Fire rating (exterior / roof)
  - (Fire) Sprinklers
  - Brush Free Zone
  - Fire Access
  - Vegetated Roofs

- Health Code
  - "Rain harvesting" / water source standards

- Covenants / Maintenance Agreements
  - HOA power to assess fees, apply liens,
  - Provide authority to jurisdiction to perform maintenance
  - Prevent additional impervious area
  - "Dangerous tree" policy

- Enforcement

It is beyond the scope of this paper to discuss all code changes required to implement LID (65/0) standards. Instead, examples of code changes are presented regarding roads and streets design.

Examples: Roads and Streets Design Code

Roads and streets comprise about half the impervious area in single-family, residential construction. In addition, they are the source of most of the pollution associated with urban runoff. Road design represents the greatest challenge in effecting the LID (65/0) standard. The following design prescriptions are proposed:

One-Way Streets and Queuing Streets Minimize Impervious Area

Queuing streets are one-lane roadways that serve traffic in two directions by requiring one or both approaching cars to pull over (in turnouts or on shoulders) to allow the other's passage. One-way streets provide for reduction of impervious surface—the best way to reduce impacts. Currently few if any jurisdictions have a standard allowing construction of one-way and/or queuing streets. Code should require such streets wherever they are practical and where their use reduces impervious area.

Pervious Materials

Paving materials are now available that provide 100% infiltration of runoff in the road prism. The combinations of pervious pavers, porous concrete, grass pavers, cellular confined rock, California strips, etc that might be allowed or required are legion. Some combination of surfaces and road prism design to limit or eliminate runoff can be conceived for every road type from neighborhood lanes to freeways. In the Evergreen State College "Toward Zero Impact" study (SCA Consulting Group, 2000), 15 such conceptual designs were identified and in no sense was this set considered exhaustive.

Many conceptual designs to date have assumed treatment of runoff in the road ballast before infiltration. This concept may be practical for low volume roads, but might present maintenance problems for high volume roads. Designs that provide treatment at the ground surface are preferred where practical. Several such designs exist in concept.

Municipal code must show street cross-sections that allow pervious systems. Infiltration through pavement implies that treatment and storage is provided in the ballast before runoff is infiltrated. Many alternatives to meet treatment and storage needs exist. These must be described and guidance must be provided to code administrators for granting of variances to allow them.

Bioretention (It used to be called "the forest")

Bioretention facilities are stormwater treatment and infiltration areas with deeply amended soils, planted in hydrophilic vegetation (Prince George's County 1993). Such soil/vegetation profiles are similar to soil horizons in old growth forests in the northwest. If the construction site is forested, it is proposed that the forest (protected against disturbance) be accepted as a bioretention facility.

Bioretention facilities provide treatment, retention, and evapotranspiration of runoff. When placed parallel to a roadway with sufficient width and at the correct grade, they can eliminate overland-flow runoff from the road right-of-way. If the road right-of-way were to meet LID 65/0 standards, the bioretention facility width would be nearly double the road width. If the road right-of-way is to serve as the forest "tract" providing all or a portion of the 65% forest-cover for the project, then it will be wider still.

Placing the forest tract (bioretention facility) in the road right-of-way has several advantages. This arrangement "disperses the forest" through the project, thus eliminating the need to convey water to the forest for dispersal. This practice also provides a safety factor for infiltration of road runoff. Furthermore, part of the roadside bioretention uses the space allocated to the planting strip found in traditional development, and, in a sense, is "free" land converted to a new purpose. Placing the forest in the road right-of-way also gives homeowners the sense that their lot is bigger and thus their privacy greater. Having the forest (bioretention facility) in the road right-of-way also provides permanent, enforceable protection from encroachment.

Sizing of bioretention facilities to meet LID 65/0 standards is a work in progress. In Prince Georges County, Maryland, the ratio calculated for bioretention area to impervious area is about 7%. But Prince Georges County doesn't have an LID standard but rather treats bioretention as a "presumptive" standard BMP.

Bioretention facility sizing to achieve zero overland flow runoff is not subject to "calculation" in the traditional sense (as when sizing a BMP). The infiltration rate through till is not easy to measure as it is in more porous soils. A standard test for infiltration in till might yield zero, or perhaps even a negative infiltration rate. Yet we know from model studies that infiltration through till is more than 13 inches per year on average (Beyerlein 1998). How then can calculations justifying bioretention facility sizing be performed?

For the Prince George's County bioretention system design, a "safety net" may be provided in that under-drains may be used to prevent the facility from being overwhelmed. Unfortunately, underdrains are devices to create "effective" impervious area. The LID (65/0) standard implies that, regardless of how slow is the infiltration rate, no runoff is allowed, even via underdrains. Thus the requirement to infiltrate runoff cannot be side-stepped.

Although infiltration is possible, even in the worst of soils, it can be so slow as to be not subject to measurement. The experience with the City of Seattle's SeaStreet project (Horner 2003) indicates that a bioretention-facility-area to road-area ratio approaching 150% provides excellent results, infiltrating almost all of the annual runoff for the basin for the first two years in operation. But, results for Seattle's pilot project were beyond those that were predicted (in part because there is no reliable way to measure infiltration through till soils). Again, if bioretention sizing cannot be done with traditional calculations, how can there use be justified to development review staff?

For bioretention facilities to meet the LID 65/0 standard, it is suggested that 200% (ie, 2:1) ratio of bioretention facility to impervious area be made a presumptive standard. This ratio is nearly 30 times that used in Prince Georges County. "Bioretention" clearly was redefined by the City of Seattle in its SeaStreet project and is defined again herein in order to satisfy the LID 65/0 standard. It is suggested that if bioretention facilities meet this "presumptive" standard no "calculations" (in the traditional sense) be required to justify the design. (See section on "Failure Criteria" below).

Code must be written that prescribes:

- Minimum bioretention facility dimensions.
- Minimum storage in the bioretention facility.
- Soil amendments and plants (if the forest must be restored).

Walkways

Walkways can be included in the road right-of-way (as is traditional), but it is suggested that, instead, code prescribe that they be placed on the back lot line. This design reduces by 50% the area of walk needed for a housing project, it isolates impervious area (thus imposing less of a burden on local soils to absorb runoff), and provides an opportunity for a strip of forest preserve in the walkway right-of-way between lots to help satisfy the 65% forest cover requirement.

Clear Zones

Clear zones are areas adjacent to roadways kept free of trees and woody vegetation. They provide a "recovery zone" for motorists who accidentally leave the roadway. Such zones reduce the area available to support large conifer trees. Evergreen trees have the highest winter evapotranspiration rate and are best suited to keep soils from over-saturating.

Existing roadway design guidelines apparently allow elimination of clear zones for low traffic-volume roads. Design guidance provided by AASHTO (2001) states that clear zones are "not generally cost effective" and "have only limited safety benefits" on low volume roads. It further states that where constraints of cost, terrain, right-of-way, or potential social/environmental impacts apply, clear zones may be eliminated (page 48).

It is suggested that neighborhood streets and lanes be considered "low-volume" roads and be excused from recovery zone requirements in municipal design code in order to increase the probability that bioretention facilities will never fail to absorb road runoff.

Road Prism Design

Generally LID (65/0) roads should be constructed above existing grade high enough to be free draining (without the need for ditches) and so that drainage is always toward associated bioretention facilities.

Curbs should be omitted. Alternatives to curbs should be considered to keep parking cars from leaving the roadway if that is a jurisdiction priority. Slotted or pervious curbs might be allowed, but should be avoided if alternatives are available. In traditional road design, it is usual practice to balance cuts and fills in order to minimize earthwork. However, for projects designed to meet 65/0 standards on poor soils, road cuts are problematic. Cuts in till soils will likely cause the road prism to be embedded in the "hardpan". This condition makes infiltration, even in modest volumes, problematic. Simultaneously it becomes impossible to drain roadways to adjacent bioretention facilities. Road cuts could be widened to include roadside bioretention facilities, but the exposed till soils would have to be compost-amended to simulate the forest and soil that was cut away. These would be expensive cuts. The alternative is to collect runoff at cut sections and convey it to down-gradient bioretention facilities. However, the practice of conveying runoff is fraught with danger (of overloading already saturated soils especially in road saddles) and should be avoided.

Code should provide allowances for innovative LID (65/0) road designs in variance procedures. For example, code should allow experiments in road designs that require little or no disturbance of soils in their construction. One of many such concepts, a road that requires no excavation for its construction, is shown in Figure 1.

Roads on Slopes

Roads that are constructed perpendicular to contour lines result in the least volume of cuts into the soil. Thus to the extent practical roads should run crosswise to contour lines. It is suggested that the maximum grade in road design code for neighborhood streets be increased to at least 12%.

Bioretention facilities adjacent to climbing road grades must be protected against channeling of flow as it leaves the pavement. Ballast under steep roads must be protected against "piping". It is suggested that code require berms at intervals in bioretention facilities on grades to be constructed perpendicular (or oblique) to the road edge. Ballast in roads must be designed to prevent piping.

Where it is impractical to construct perpendicular to contours, it is suggested that roads on steeper slopes be limited to one-way and the bench cut into the existing grade to accommodate the road be minimized. It is also suggested that where practical, the road surface be raised up equal to existing grade on the up-hill side. (See example, Figure 2). This design minimizes the daylighting of interflow runoff—a condition that might lead to surface runoff.

Roads built on side-hill cuts (ie, parallel to contours) must have the associated bioretention facilities (existing or restored forest) located on the downhill side. In order for the road to drain to the bioretention facility, the crown must be eliminated and it must slope down-gradient. Narrow roads reduce cut volumes. (See Figure 3). Where this design is impractical (eg, the road is rounding a hill thus requiring superelevation in the "wrong" direction), the road surface could be constructed of pervious materials, obviating the need for "counter" superelevation. Runoff in this case penetrates the road surface and moves down-gradient under the road to the bioretention facilities.

Ditches should not be constructed on roads on a side slope. Such ditches cause runoff to concentrate, a violation of LID 65/0 standards.

Driveways and Curb Cuts for Driveways

Driveway crossings over bioretention facilities should be minimized. Sharing driveways (eg, at every other lot line) is one way to do this and code should encourage this practice. Driveways should be as narrow as practical and should be made of grass-block pavers or other pervious material. Curbs should not be included in design options, but if they are they should be porous or slotted.

Cottage style development typically provides common parking areas thus minimizing driveway bioretention crossings. Cottage and co-housing style development should be encouraged in zoning code.

Alleys

Alleys located on one side of homes (and streets on the other) cause dwelling units to be nearly surrounded with impervious surface. Alleys provide redundant (unnecessary?) access for autos at the expense of forest preservation and pedestrian safety. It is recommended that code disallow alleys.

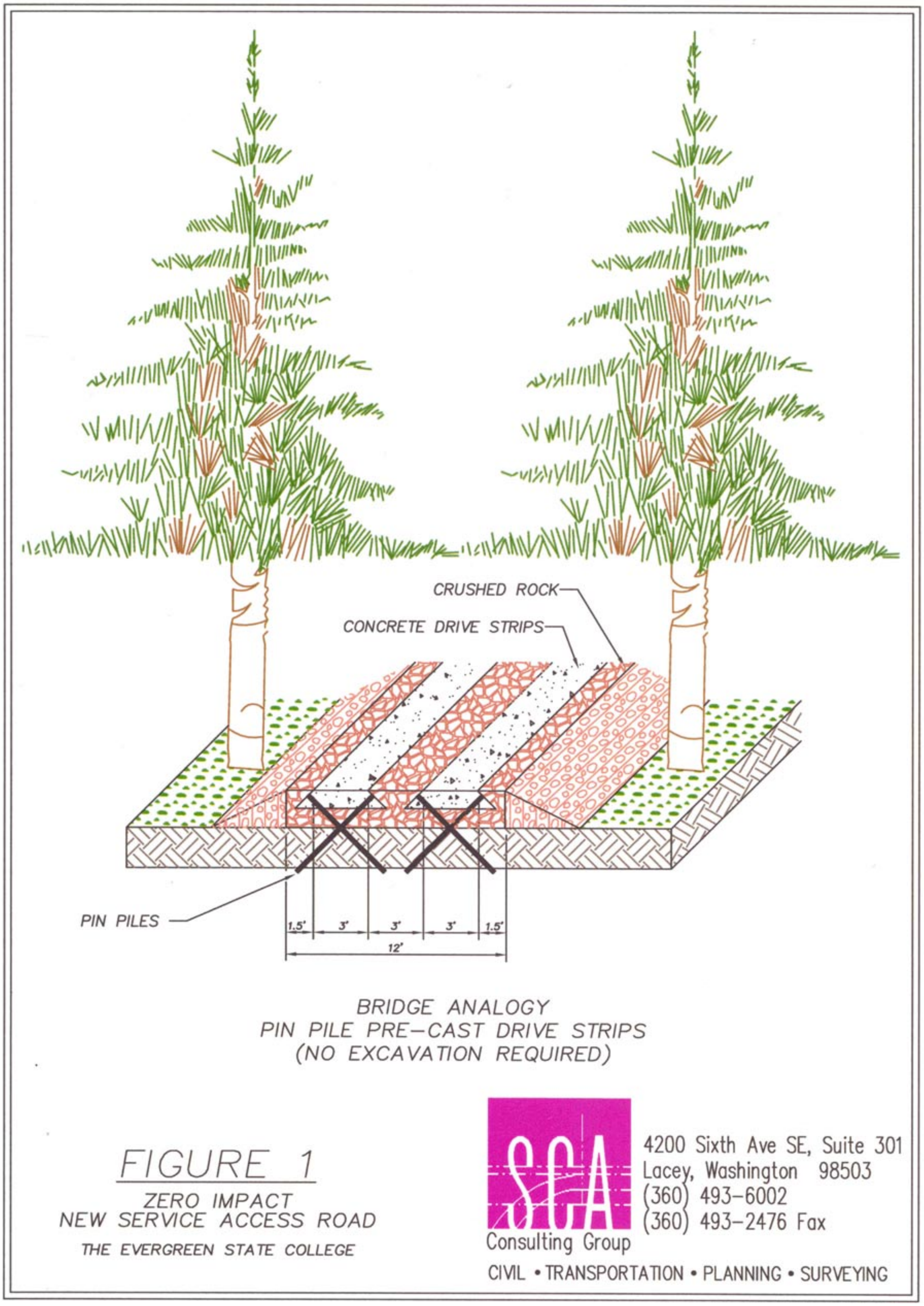

Figure 1. Low volume road partially supported by piles needs little or no excavation in its construction.

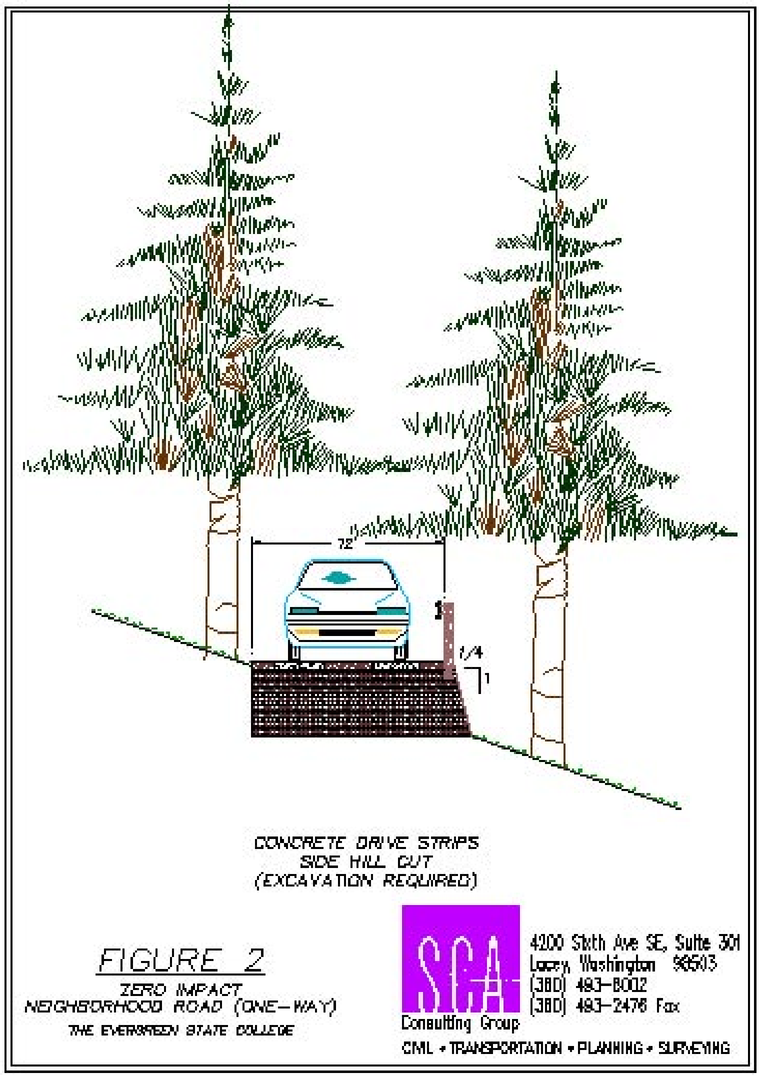

Figure 2. Impact of roads on slopes can be minimized using soil reinforcement to reduce side casting. The bench in the slope is filled to meet the up-hill existing gradient to minimize changes in shallow groundwater movement. Absence of ditches eliminates concentration of runoff.

Failure Criteria

Many jurisdictions have expressed concern about the possible "failure" of LID designs. They suggest that code should require construction of parallel storm drainage systems in case LID "doesn't work". In effect they are saying that if there is a chance (regardless of how small) that LID will "fail", municipal code should require the option to revert to a system that is certain to fail (discharging to surface water has been the cause of destruction of many streams). Such code would be against the interests of the jurisdictions and would lead to very expensive duplication of systems that would be resisted by the development community perhaps putting the standards at risk.

But jurisdictions' concern begs the question: "How do we define failure?" Would wet soils or puddles in the forest constitute failure? Only if wet soils translated into wet basements. Does occasional ponding or flowing of runoff that cannot be immediately infiltrated mean failure? It is failure only if runoff leaves the site, covers roadways, or flows into living spaces.

Rather than consider reversion to a failed paradigm (ponds and outfalls) as a fallback position, it is suggested that a better approach to meet concerns is to provide safety factors in the LID design. That is, roadway and structure designs should accommodate occasional wet soils, should foresee and mitigate for ponding, and should make damage from such events unlikely.

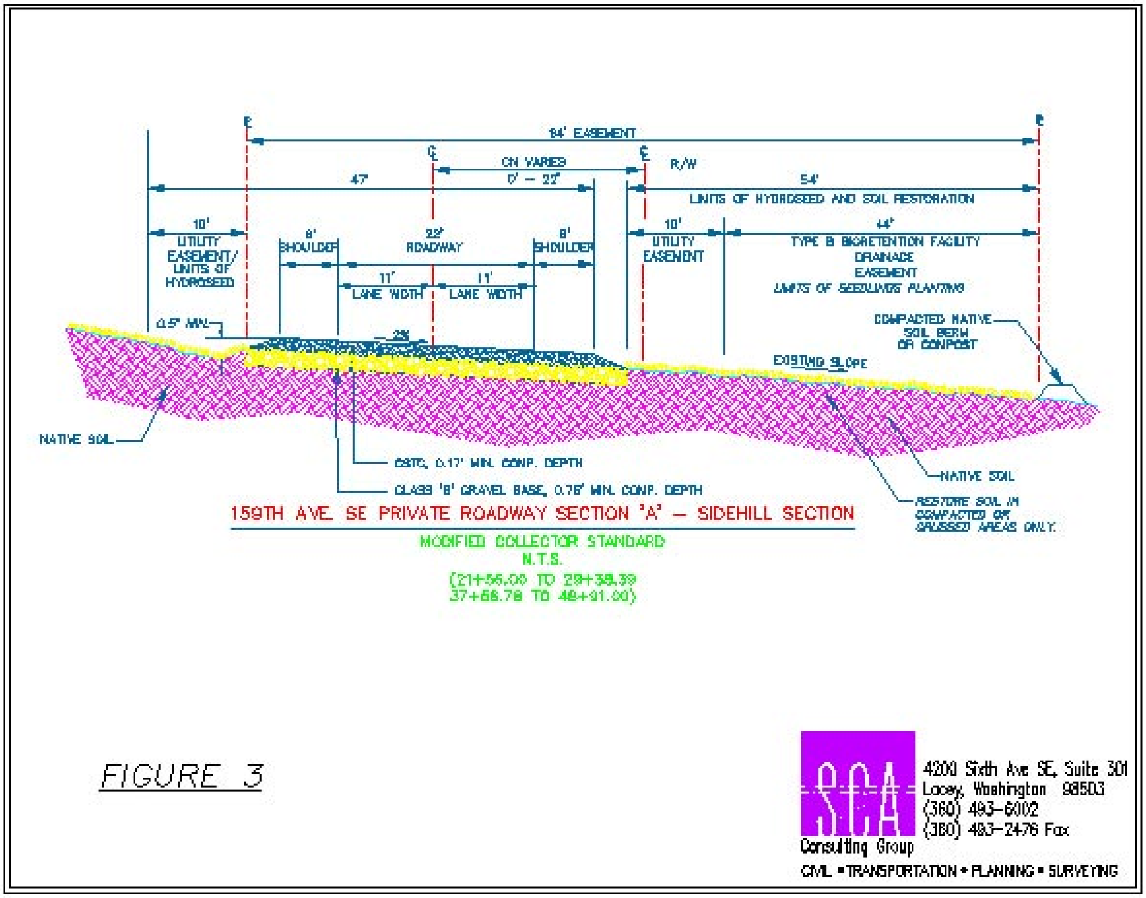

Figure 3. On sloped ground, bioretention facilities should be placed down-gradient of the road implying eccentric location of road centerline within the right-of-way.

There are many examples of how design could provide safety factors to alleviate jurisdictions' concerns. Bioretention facilities should be designed to prevent conveyance. For example, if there is a concern that bioretention facilities will not absorb road runoff from very large events, design the bioretention facilities bigger and the roads smaller and more pervious; or make the ground rougher in the facilities to provide more surface storage; or plant more vegetation. If there is a concern about wet basements, do not allow the construction of basements. If there is a concern about occasional ponding, provide that roads and structures be constructed above estimated depth of ponding. If there is a concern about flow down steep grades, contour plow the grade or provide berms or check dams on such slopes and plant them with vegetation that creates root mats. In short, provide factors of safety that enhance, not subvert, LID (65/0) goals.

Conclusion

Importance of Getting It Right

Our leaders tell us that it is inevitable that population will double in the northwest in the next 4 or 5 decades and, in that brief span, as much land will be converted from forest and farm to urban purposes as has been previously converted in all of human history. If any of our streams in the path of development are to survive this unprecedented rate of land use conversion, it is important that LID standards be tight and conservative. Errors or misjudgments in creating the code can lead to grievous consequences for aquatic life.

Few Templates Available

Existing code requiring high-impact development is built upon experience dating back decades if not centuries. We are now contemplating a paradigm shift for development for which it is difficult to find a comparison. LID (65/0) code must be new-minted with little in the way of existing code to guide us.

In the author's opinion, the performance-based code closest to a LID 65/0 development standard is the City of Tumwater's (WA) Title 13, Chapter 13.22.

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*Salmon In the City Conference abstracts (1998) may be found on the Internet at: http://depts.washington.edu/cwws/Research/Reports/salmoninthecity.pdf. It is listed on the publications (books and articles) page in the information transfer section.